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YIELD PERFORMANCE OF AN INTRODUCED JAPONICA RICE VARIETY IN THE TEXAS GULF COAST[1]

H.M. Beachell and N.S. Evatt[2]

Introduction

In the Southern rice area of the United States (Texas, Arkansas, Louisiana, and Mississippi) acre yields of rough rice normally average about 1000 pounds less than in California. A portion of this difference may be due to differences in the yielding potential of the varieties grown.

Long and medium-grain varieties comprise most of the rice acreage in the Southern area. Most of the long-grain types were developed as selections from and crosses between indica types introduced from the Philippines and Taiwan, whereas the medium-grain types were developed from indica-japonica crosses. The high-yielding japonica short-grain varieties Caloro and Colusa make up the bulk of the California acreage. These varieties are not adapted to commercial production in the Southern area because of their weak straw, difficult threshing, and lack of dormancy of grains when harvested.

A japonica type variety, P.I. 215936 (Tainan-iku No. 487) introduced from Taiwan, appears to be better adapted to the Southern rice growing areas than Caloro and Colusa. P.I. 215936 develops shorter, sturdier straw than the California varieties and does not show their sensitivity to day length. P.I. 215936 is a variety from Taiwan of the Ponlai (5) or Horai type varieties (4).

Materials and Methods

The yielding ability of P.I. 215936 was compared with that of Bluebonnet 50, a leading Texas long-grain variety, by growing in fertility and date-of-seeding experiments for 2 years (1959-60). Each experiment was designed as a randomized block, split-plot experiment.

Varieties were used as main blocks in the fertility experiment. The sub-plots were composed of a 4×3 complete factorial design within each variety. Nitrogen rates (40, 80, 120, or 160 pounds per acre) and phosphorus (P_2O_5) rates (0, 40, or 80 pounds per acre) were the variables. Sub-plots were 4×30 feet in size. The experiment was seeded the latter part of April at a rate of 90 pounds of rough rice per acre and replicated 4 times. Crystalline ammonium sulphate and 46 percent superphosphate were used as nitrogen and phosphorus sources. Fertilizer was applied by hand on dry soil 20 to 30 days after seeding.

Seeding date was the main block with varieties as sub-plots in the date-of-seeding experiment. The plots were replicated 3 times and sown in early April, May, and June at a rate of 75 pounds of rough rice per acre. Each sub-plot (6×16 feet) received a uniform application of 80 pounds of nitrogen and 40 pounds of phosphorus (P_2O_5) per acre. Pelletized Ammophos[3] (16-20-0) was used as the phosphorus source and for 32 pounds of the nitrogen. The rest of the nitrogen was from crystalline ammonium sulphate. The fertilizer was applied by a mechanical distributor on dry soil 20 to 30 days after seeding.

The soils were Beaumont clay, typical of much of the Texas rice belt clays (2)

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1 Contribution from the Crops Research Division, Agricultural Research Service, U.S. Department of Agriculture, the Texas Agricultural Experiment Station, and the Texas Rice Improvement Association.

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3 The mention in this publication of a trade product, equipment, or a commerial company does not imply its endorsement by the U.S. Department of Agriculture over similar products or companies not named.

and (6). Soil tests indicated that they were low in nitrogen and available phosphorus (P_2O_5) and from medium to high in potash (K_2O).

Results

Fertilizer Experiment

Significant differences in yield occurred between the two varieties in the fertilizer experiment as shown in Table 1. There were significant differences in yield due to nitrogen rates and nitrogen rate-variety interactions. Similar nitrogen rate-variety interactions have been reported at Beaumont and elsewhere (1,3). The 2-year average yield of P.I. 215936 for all treatments (48 plots) was 1235 pounds per acre higher than for Bluebonnet 50. P.I. 215936 yielded highest at the 160-pound nitrogen rate (5501 pounds) whereas Bluebonnet 50 yielded highest at the 80-pound rate (4014 pounds). The Bluebonnet 50 yield was but 3219 pounds at the 160-pound rate.

Each year 4 non-fertilizer border plots of both varieties were grown as observational check plots. P.I. 215936 averaged 3355 pounds per acre compared with 2838 pounds for Bluebonnet 50.

Date of Seeding Experiment

Average rough rice yields of the two varieties in the date-of-seeding experiment (Table 2) were in general agreement with the yields recorded in the fertilizer experiments. P.I. 215936 rough rice yields averaged 1041 pounds per acre higher than those of Bluebonnet 50, and the total milled rice yield for P.I. 215936 was 4.0 percentage points higher than for Bluebonnet 50. Both varieties matured at about the same time, but the plant height of P.I. 215936 averaged 7 inches shorter than Bluebonnet 50.

TABLE 1

Average rough rice yields of Bluebonnet 50 and P.I. 215936 receiving different rates of nitrogen fertilization, Beaumont, Texas, 1959-60.

Nitrogen per acre (lbs.)	Yield per acre* Bluebonnet 50 (lbs.)	P.I. 215936 (lbs.)	Average (lbs.)	Varietal Difference (%)
40	3329	3932	3630	18.1
80	4014	4751	4382	18.4
120	3929	5248	4588	33.6
160	3219	5501	4360	70.9
Average	3623	4858	4240	34.1

	Rough rice yield per acre: Nitrogen	Variety	Nitrogen×Variety
* Least Significant Difference (.01)	189	216	267

TABLE 2

Average rough rice yields and other data recorded on Bluebonnet 50 and P.I. 215936, sown at different dates, Beaumont, Texas, 1959-60.

Variety and Seeding date	Seeding to maturity (days)	Plant Height (in.)	Rough rice yield per acre (lbs.)	Milling Yield: Head Rice (%)	Milling Yield: Total Rice (%)	Total rice per acre (lbs.)	Total rice per acre: Varietal Difference (%)
Bluebonent 50 :							
April 4	143	40	3356	62.9	68.9	2306	
May 4	131	51	3049	54.7	64.9	1974	
June 13	127	50	3401	64.6	69.4	2356	
Average	134	47	3269	60.7	67.7	2212	
P.I. 215936 :							
April 4	148	37	3745	65.9	69.9	2614	13.4
May 4	132	42	4192	70.0	72.2	3026	53.3
June 13	122	44	4994	57.1	72.9	3644	54.7
Average	134	41	4310	64.3	71.7	3095	39.9

	Rough rice yield (lbs. per acre)	Total milled rice (percent)
Least Significant Difference (varieties)	903 (.01 level)	3.3 (.05 level)

Discussion

The higher average yields produced by P.I. 215936 were thought to have been due in part to certain plant characteristics common to most japonica varieties.

P.I. 215936 develops shorter and smaller stems and shorter and more narrow leaves than Bluebonnet 50. In Texas under favourable weather and soil conditions, Caloro produces yields comparable with those of P.I. 215936, but usually grows taller and has weaker straw than P.I. 215936. The more willowy straw of the japonica varieties makes them more susceptible to lodging. In spite of potentially high yielding capacity, P. I. 215936 and other japonica varieties are seldom grown commercially in Texas because these varieties are difficult to thresh. Also, the grains are more apt to germinate if humid weather persists for several days just prior to harvest. The long-grain varieties now grown in Texas exhibit a moderate degree of dormancy at time of ripening; therefore, germinating of grains before harvesting is not a serious problem with the long-grain varieties except when the crop is lodged 10 or more days prior to harvest.

Through breeding it should be possible to develop adapted high-yielding varieties possessing many of the desirable features of P.I. 215936.

Summary

Rough rice yields, plant height, time of maturity, and milling yields of Bluebonnet 50, a leading Texas long-grain variety, were compared with those of a short-grain japonica variety (P.I. 215936) introduced from Taiwan. Two years data from small plots showed that P.I. 215936 produced significantly higher rough and total milled rice yields than did Bluebonnet 50. A highly significant nitrogen-variety interaction was noted.

The lack of seed dormancy and the difficulty of threshing preclude the acceptance of P.I. 215936 as a commercial variety in Texas. However, its desirable features may be of value to plant breeders in the development of higher yielding varieties for the Southern rice area of the United States.

References

Evatt, N.S. and Beachell, H.M.
Rice variety-fertilizer tests at the Rice-Pasture Experiment Station, 1955-57. Texas Agr. Exp. Sta. Progress Report 2065. Dec. 1958.

Evatt, N.S. and Beachell, H.M.
Ratoon cropping of short-season rice varieties in Texas. IRC Newsletter Vol. IX, No. 3, pp. 1-4. Sept. 1960.

Evatt, N.S., Johnston, T.H., and Beachell, H.M.
The response of short-strawed rice varieties to varying levels of nitrogen fertilization. IRC Newsletter, Vol. IX, No. 3, pp. 5-12, Sept. 1960.

Iso, Eikichi.
Rice and Crops in Its Rotation in Subtropical Zones. Japan FAO Assoc., Tokyo. 611 pp. 1954.

Miu, Tsin-san.
A photographic monograph on the rice varieties of Taiwan Agr. Res. Inst., Special Pub. No. 2. 1959.

Reynolds, E.B.
Research on rice production in Texas. Texas Agr. Exp. Sta. Bull. 775. May 1954.

COMPARATIVE REACTIONS OF RICE VARIETIES TO THE STRIPE AND HOJA BLANCA VIRUS DISEASES[1]

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Foliar symptoms of the stripe disease of Japan and hoja blanca disease of the Western Hemisphere are similar, as pointed out in the early papers on hoja blanca (2, 3, 4). After hoja blanca was recognized in 1956 as a serious new rice disease in Cuba and Venezuela and a threat to the United States rice crop (1), varietal reaction testing was initiated in 1957 by the United States Department of Agriculture, in cooperation with public and private organizations in areas where the disease occurred. Many of the rice varieties rated as resistant in the 1957 tests were Japonica types (2). According to the information available to the senior author at that time, none of the Japanese rice varieties was considered to be resistant to the stripe disease in Japan.

In 1957 arrangements were made to determine the reactions to stripe of a group of 8 rice varieties with known reactions to hoja blanca. It was thought that the comparative varietal reactions to the two diseases would indicate whether they were the same or different. At that time hoja blanca was considered to be caused by an insect-transmitted virus but different from the stripe disease. While the insect vector for hoja blanca was not known, the insect vector for the stripe disease virus, *Delphacodes striatella*, had never been collected in the Western Hemisphere. Mukoo and Iida (4) noted that leaf symptoms of hoja blanca in Cuba differed in certain respects from those of the stripe disease in Japan.

In Japan several United States varieties were tested, along with a large number of Japanese varieties, for reactions to the virus causing stripe disease. Table 1, compiled from the information obtained in Japan on reaction to stripe and from the results obtained in the 1957, 1958 and 1959 hoja blanca nurseries, gives the reactions of 91 rice varieties to stripe and hoja blanca. The reactions reported indicate that these diseases are caused by different viruses since the varietal reactions were not correlated.

References

1. Adair, C.R., and J.W. Ingram. 1957. Plans for the study of hoja blanca, a new rice disease. *Rice J.* 60 (4): 12.
2. Atkins, J.G., and C.R. Adair. 1957. Recent discovery of hoja blanca, a new rice disease in Florida, and varietal resistance tests in Cuba and Venezuela. *Plant Disease Reptr.* 41:911-915.
3. Malaguti, G. 1956. La "hoja blanca", extrana enfermedad del arroz en Venezuela. *Agronomia Tropical* 6:144-145.
4. Mukoo, H., and T. Iida. 1957. Informe sobre la investigacion de la hoja blanca del arroz en Cuba. *Administracion de Establizacion del Arroz Bol.* No. 1:5-12.

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1 Research conducted cooperatively through informal arrangements between Crops Research Division, Agricultural Research Service, United States Department of Agriculture; National Institute of Agricultural Sciences, Tokyo, Japan; and Kanto-Tosan Agricultural Experiment Station, Konosu, Japan.

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TABLE 1

Reactions of rice varieties to stripe and hoja blanca

FAO Stock No.	C.I. or[1] P.I. No.	Variety name	Source	Reaction to Stripe[2]	Reaction to Hoja Blanca[3]
223	202943	Aichi-Asahi	Japan	SS	R
	162072	Aikoku 1	Japan	M	S
889	224792	Aimasari	Japan	M	R
	8312	Asahi	Japan	S	R
	162076	Asahi 4	Japan	S	R
578	226157	Ayanishiki	Japan	S	R
893	224798	Benisengoku	Japan	S	R
1012	8990	Bluebonnet 50	United States	M	S
217	2128	Blue Rose	United States	M	S
	168945	Bomba	Spain	M	S
211	1561-1	Caloro	United States	M	S
	1645	Carolina	United States	RR	S
1014	8993	Century Patna 231	United States	RR	S
579	226159	Chukyo-Asahi	Japan	SS	R
318	224803	Daikoku-Wase	Japan	M	S
220	1344	Fortuna	United States	S	S
319	224805	Fukubozu	Japan	M	S
577	184499	Fujisaka 5	Japan	M	R
227	226162	Futaba	Japan	SS	R
	9416	Gulfrose	United States	(RR)	R
904	224814	Hatsushimo	Japan	SS	R
908	224818	Hikari	Japan	M	R
909	224824	Hozakae	Japan	S	S
	9368	Hybrid Mix. Selection	United States	(RR)	R
913	224829	Kamenoo 1	Japan	R	S
580	226174	Kin Maze	Japan	SS	R
229	226175	Koganemaru	Japan	SS	R
918	202975	Kotobuki-Mochi	Japan	SS	R
	202979	Kyto-Asahi	Japan	SS	R

1 Accession number, United States Department of Agriculture

2 RR = Very resistant
R = Resistant
M = Moderately susceptible
S = Susceptible
SS = Very susceptible
( ) = Tested only one year

3 R = Resistant
MR = Moderately resistant
S = Susceptible

TABLE 1 (Contd.)

FAO Stock No.	C.I. or P.I. No.	Variety name	Source	Reaction to Stripe	Reaction to Hoja Blanca
1017	8985	Lacrosse	United States	M	R
216	8318	Magnolia	United States	R	S
1135	9155	Mo. R-500	United States	(RR)	R
256	224847	Naguraho	Japan	M	R
1133	8998	Nato	United States	(RR)	S
215	2702	Nira	United States	R	S
289	224850	Norin 1	Japan	R	R
258	224852	Norin 6	Japan	S	R
259	202986	Norin 8	Japan	S	R
930	224854	Norin 10	Japan	M	R
275	202987	Norin 12	Japan	M	R
	162117	Norin 13	Japan	SS	R
299	224857	Norin 14	Japan	R	R
284	224858	Norin 16	Japan	M	R
285	224859	Norin 17	Japan	M	R
931	224863	Norin 21	Japan	M	R
260	224864	Norin 22	Japan	S	R
261	224865	Norin 23	Japan	S	R
932	224866	Norin 24	Japan	R	R
300	224867	Norin 25	Japan	S	R
933	224869	Norin 29	Japan	S	R
	222501	Norin 31	Japan	S	S
934	224870	Norin 32	Japan	S	R
935	224872	Norin 35	Japan	S	R
936	224874	Norin 37	Japan	SS	R
938	224876	Norin 41	Japan	S	R
939	224877	Norin 44	Japan	SS	R
940	224878	Norin 48	Japan	M	R
944	224882	Obanazawa 1	Japan	S	R
209	8311	Prelude	United States	(R)	S
1111	239073	Reishiko	China	SS	S
263	226184	Rikuto-Norin 12	Japan	RR	S
264	226190	Rikuto-Norin 21	Japan	RR	S
280	224889	Rikuto-Norin 9	Japan	RR	S
281	224891	Rikuto-Norin 24	Japan	RR	S

TABLE 1 (Contd.)

FAO Stock No.	C.I. or P.I. No.	Variety name	Source	Reaction to Stripe	Reaction to Hoja Blanca
954	226191	Rikuto-Norin Mochi 26	Japan	RR	S
322	224893	Rikuu 132	Japan	R	R
302	224894	Saitama-Mochi 10	Japan	M	R
959	224898	Sasashigure	Japan	M	S
228	226202	Senbon-Asahi	Japan	SS	R
962	226203	Sen-ichi	Japan	M	MR
965	224903	Shimotsuki	Japan	M	R
290	224904	Shin 2	Japan	M	S
967	224906	Shin 7	Japan	S	R
	203004	Shinju 1	Japan	SS	R
969	224908	Shinano-Mochi 3	Japan	M	R
971	224912	Shirogane	Japan	S	R
230	226206	Shuho	Japan	SS	R
1004	218875	Taichung (Taichu) 65	Taiwan	M	R
975	224915	Takanenishiki	Japan	M	R
277	224916	Takara	Japan	M	R
976	226209	Takenari	Japan	M	R
581	226211	Tokai-Asahi	Japan	M	R
981	226212	Tokaisenbon	Japan	S	R
983	224924	Tonewase	Japan	R	R
1134	9013	Toro	United States	(RR)	S
1112	239074	To-to	China	SS	S
985	224930	Tsurugiba	Japan	S	R
988	224935	Yachigogane	Japan	M	R
989	224938	Yuubae	Japan	R	R
206	7787	Zenith	United States	R	S
287	224939	Zuiho	Japan	M	S

MECHANISM OF RESPONSE TO HEAVY MANURING IN RICE VARIETIES

I. Baba[1]

In order to promote the breeding of improved varieties which readily respond to heavy manuring, it is important to elucidate the mechanism of response to heavy manuring as well as the contributory plant charactors affecting this mechanism. In this paper, recent results of physiological and morphological investigations on the problem obtained in Japan are reported.

I. Physiology of rice plant in relation to response to heavy manuring

1) Changes in yield components by nitrogen supply.

In general, with an increasing nitrogen supply, the number of spikelets produced per hill increases, but the ripening percentage tends to decrease with nitrogen supply beyond a certain limit. This tendency is less pronounced in the high reponse varieties than in the low response ones. Consequently, the rate of yield increase in lower response varieties-but not in higher response ones–goes down, not keeping pace with the increase of nitrogen supply. Weight of 1,000 perfect grains showed no definite relation to nitrogen supply or to degree of response of varieties (Table 1). Ratio of grain weight to straw weight decreases also with the increase of nitrogen supply, and here again the decrease is less with high than with low response varieties.

2) Accumulation and translocation of carbohydrate.

The fact that the high response varieties manifest a smaller degree of lowering the grain-straw ratio by heavy manuring and also a smaller degree of lowering the ripening percentage for the increased number of spikelets suggests that the accumulation of carbohydrate and the translocation of it to the panicle might be greater with high response varieties for increased leaf growth (an increase in leaf area). Results obtained with medium duration varieties differing in degree of response are given in table 2. Decrease in starch content in leaf sheath + stem caused by nitrogen supply is more conspicuous with the low response variety, indicating a great reduction in starch accumulation under heavy application of nitrogen. This might be attributed to the fact that :—

a) Low response varieties, as compared with high response varieties, absorb much more nitrogen at the early growth stage, and make greater growth and leaf area development. It means that most of the photosynthetic product is utilized to form cell membrane substances (cellulose, lignin), leaving only a small portion of carbohydrate to be stored in the form of starch.

b) Table 3 gives an example of how the increase in lignin content or lignin + cellulose content due to the increase of nitrogen supply is greater with the low response variety.

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TABLE 1

Effect of nitrogen application on yield and yield components

Variety	Response to heavy manuring	Plot	Perfect paddy weight per hill (%)	Total number of spikelets per hill (%)	Ripening percentage (%)	Weight of 1000 perfect grains (%)	Paddy weight / Straw weight (%)
		N_1	100	100	100	100	100
Norin 25	high	N_2	117	121	97	99	100
		N_3	123	149	84	98	91
		N_1	100	100	100	100	100
Chiba-asahi	low	N_2	115	117	99	100	98
		N_3	106	115	94	99	84
		N_1	100	100	100	100	100
Kinmaze	very high	N_2	106	115	95	99	93
		N_3	120	127	97	99	95
		N_1	100	100	100	100	100
Norin 8	medium	N_2	109	109	101	99	95
		N_3	109	123	89	99	80

All figures are expressed as percentages, taking the value of N_1 as 100. N_1, N_2 and N_3 indicate the level of nitrogen application, N_1 is the lowest and N_3 the highest.

TABLE 2

Effect of nitrogen application on the starch content in leaf sheath + culm

Variety	Response to heavy manuring	Starch content in leaf sheath + culm (%)					
		16 Aug.			Full heading time		
		N_1	N_2	N_3	N_1	N_2	N_3
Norin 25	high	9.60	8.76	8.28	8.64	8.28	7.32
Chiba-asahi	low	12.00	9.36	6.75	9.74	7.68	5.64
Kinmaze	very high	10.92	9.51	9.27	9.48	7.44	7.44
Norin 51	medium	9.87	9.03	7.35	10.43	9.52	7.72

TABLE 3

Effect of nitrogen application on lignin and cellulose content in straw

Variety	Response to heavy manuring	Plot	Lignin and cellulose content in straw (%)					
			16 Aug.			Full heading time		
			Lignin	Cellulose	Total	Lignin	Cellulose	Total
Norin 25	high	N_1	2.9	21.3	24.2	4.8	21.3	26.1
		N_2	3.4	22.4	25.8	4.8	21.8	26.6
		N_3	3.3	22.4	25.7	5.2	23.7	28.9
Chiba-asahi	low	N_1	2.9	22.3	25.2	4.3	21.3	25.6
		N_2	3.3	22.2	25.5	4.8	22.1	26.9
		N_3	4.3	23.1	27.4	5.9	23.6	29.5
Kinmaze	very high	N_1	2.8	20.1	22.9	4.5	20.0	24.5
		N_2	2.7	21.0	23.7	4.6	22.6	27.2
		N_3	2.9	21.2	24.1	4.8	22.5	27.2

3) Photosynthesis and respiration in relation to response to heavy manuring.

On the other hand, the accumulation of stored carbohydrate (starch) depends upon the balance between the photosynthetic production of carbohydrate and the respiratory consumption of it. Therefore, the mechanism of response to heavy manuring should be analyzed from this point of view.

Total photosynthetic production per unit field area (P) can be expressed as the product of photosynthetic rate per unit leaf area ($P_\circ$), total leaf area in unit field areas (A) and light-receiving coefficient (f), according to Murata, Osada, Iyama & Yamada (1957).

$$P = AfP_\circ \dots\dots\dots\dots (1)$$

Light-receiving coefficient (f) expresses the efficiency of plant population in utilizing light, the value of f decreasing exponentially with the increase of leaf area. Thus, with the increase of leaf area (A), total photosynthetic production (P) increases, but the rate of increase in P gradually goes down.

As the leaf area is relatively small at the lower nitrogen level, an increase in leaf area gives a proportional increase in photosynthetic production which induces greater growth and yield. On the other hand, under high levels of fertilizer application, an excessive development of leaf area takes place, which reduces the light-receiving coefficient and consequently reduces an increment of photosynthetic production. However, respiratory consumption increases in proportion to the increase in leaf area, so that the net production of carbohydrate increases only a little or sometimes even decreases.

Lowering of the light-receiving coefficient is due to mutual shading; mutual shading in a plant population reduces light intensity inside the population. Light intensity inside the plant population (I) is determined by light intensity outside the population ($I_\circ$), leaf area (F) and light-transmission coefficient (K), according to Monji & Saheki (1953).

$$I = I_\circ e^{-KF} \dots\dots\dots\dots (2)$$

where e = base of natural logarithm

Light-transmission coefficient (K) indicates the degree of penetration of light through plant populations under similar conditions of leaf area. This value varies with the leaf angle, thickness of leaf and other morphological characteristics of the plant. A low value of K indicates that the

plant has characteristics responsible for a high light receiving efficiency.

Murata & Osada (1961) observed with medium maturing varieties that lowering of the K value due to heavy manuring is greater with high response varieties, indicating a high light-receiving efficiency for a given leaf area.

Murata & Osada (1961) investigated photosynthetic production and respiratory consumption at heading time in relation to response to heavy manuring, using six varieties of each of the early maturing, medium maturing and late maturing groups. With early and medium maturing groups, it was shown that the high response varieties gave a higher ratio of photosynthesis to respiration (P/R ratio) than the low response varieties (Table 4).

TABLE 4

Effect of nitrogen application on the ratio of photosynthetic production to respiratory consumption (P/R) of plant population

Early maturing group				Medium maturing group			
Variety	Response to heavy manuring	Plot	P/R	Variety	Response to heavy manuring	Plot	P/R
Fuji-minoru	high	N_2	5.73	Hokuriku 52	high	N_2	4.70
		N_4	5.18			N_4	3.78
Fujisaka 5	high	N_2	5.75	Norin 25	high	N_2	3.83
		N_4	5.31			N_4	3.65
Akibae	medium	N_2	5.00	Yamakogane	high	N_2	4.50
		N_4	3.71			N_4	4.12
Norin 1	medium	N_2	5.85	Kiyosumi	medium	N_2	4.69
	low	N_4	4.84		low	N_4	3.69
Obanazawa 1	low	N_2	4.70	Chiba-asahi	low	N_2	3.97
		N_4	4.42			N_4	3.23
Kamenoo	low	N_2	4.37	Tamanishiki	very low	N_2	4.62
		N_4	4.30			N_4	3.49

N_2: Standard quantity of nitrogen applied, N_4: Very high quantity.

P : Photosynthetic production of plant population under 70-80 lux of light intensity,

R : Respiratory consumption of the plant population under 28° C, both expressed in term of CO_2 g/m^2 field/hour.

According to equation (1), the P/R ratio can be analyzed into four factors; light-receiving coefficient (f), photosynthetic rate per unit leaf area (P_o), respiratory rate per unit dry weight of plant (r), average of whole plant and leaf area ratio (LAR), as shown below ;—

$$P/R = \frac{fP_o A}{rD} = \frac{fP_o}{r}\frac{A}{(D)} = \frac{fP_o}{r} \times \text{LAR} \quad \ldots\ldots (3)$$

where D = dry weight of the whole plant.

By examining the change of these four factors caused by heavy applications of nitrogen, it was found that (a) in the medium maturing group the high response

varieties have in general a higher photosynthetic rate (P_o), a smaller degree of lowering the light-receiving coefficient (f), and a greater LAR, all of which causes a higher P/R ratio, and (b) in the early maturing group a higher P/R ratio is accounted for by the low respiratory rate (r).

4) Physiological activity of roots and response to heavy manuring.

Physiological activity of roots can be expressed by the activity of roots to oxidize α—naphthylamine, according to Yamada (1958). Using this technique, Iwata & Baba (1961) examined root activity with respect to oxidizing α—naphthylamine in relation to plant growth with medium maturing varieties differing in response to manuring. The results are given in Table 5. Under heavy application of nitrogen (N_3), the low response varieties show higher activity in α—naphthylamine oxidation than the high response varieties during the early growth stage (26 July), but the activity decreases markedly after the mid-season, giving very low values from then onwards.

TABLE 5

Effect of nitrogen application on the activity of roots in α—naphthylamine oxidation

Variety	Response to heavy manuring	Plot	Root activity in α-Na oxidation (r/g. DW/hr.)		
			26 July	14 Aug.	Heading time
Norin 25	high	N_1	418 (100%)	178 (43%)	112 (27)
		N_3	425 (100)	237 (56)	136 (32)
Chiba-asahi	low	N_1	411 (100)	184 (45)	123 (30)
		N_3	437 (100)	207 (47)	106 (24)
Kinnaze	very high	N_1	429 (100)	132 (31)	96 (22)
		N_3	409 (100)	181 (44)	114 (28)
Norin 8	medium	N_1	463 (100)	148 (32)	102 (22)
		N_3	437 (100)	166 (38)	110 (25)

The varietal difference in resistance to root rot caused by hydrogen-sulphide is considered to be a characteristic different to that which governs response to manuring. However, in a variety showing low response to manuring and low resistance to root rot the decrease in root activity and the occurrence of root rot should be very marked at a later stage of growth.

The fact that under high nitrogen levels the low response varieties, especially indica varieties, absorb actively much more nitrogen during the early stage of growth than the high response varieties, and that after the middle stage of growth nitrogen absorption is more suppressed in the former than in the latter, as was found by Takahashi, Iwata & Baba (1959), can now be explained by the change in root activity according to growth, as mentioned above.

Baba & Tajima (1960, 1961) observed, in a solution culture experiment that the damage done by H_2S to roots involves not only die-back of lower leaves, which decreases leaf area, but also a decreased photosynthetic rate (P) and an increased respiratory rate (R) per unit leaf area at the later growth stage. Consequently, it causes a remarkable decrease in P/R ratio per unit leaf area, which finally results in the lowering of ripening percentage and a decrease in yield. For this reason, the depression of root activity which takes place after the

mid-season of growth with low response varieties growing under high nitrogen levels could be a factor causing die-back of lower leaves and a decrease in P/R ratio per unit leaf area, resulting in a decreased P/R ratio of the whole plant and poor ripening owing to poor accumulation and translocation of carbohydrate.

Generally, it may be said that the high response varieties are adaptable to the ill-drained paddy field where root-rot occurs. This can be accounted for by the fact that these varieties are capable of maintaining a relatively high root activity even after the mid-season of growth.

5) Translocation of carbohydrate into the panicle.

Tsunoda (1960 b) observed that the increase of grain dry weight (speed of ripening) at the early stage of grain development is somewhat less in the high response varieties than in the low response varieties, but it becomes greater at the later stage of grain development while the ripening period also lasts longer with the high response varieties. The good ripening of high response varieties seems to be partly related to this phenomenon.

II. Morphology of rice plant in relation to response to heavy manuring

Tsunoda (1959, 1960 a) investigated the relation between response to heavy manuring and the morphological features connected with photosynthesis and reached the following conclusions.

Varieties suitable for light manuring are characterized by having thin and wide leaves which extend almost horizontally. By this horizontal arrangement of leaves the varieties can increase the total quantity of light to which the plants are exposed, under low level of manuring. But, under high level of manuring, the upper leaves overspread the lower leaves as a result of the horizontal arrangement of wide leaves. Consequently, the upper leaves are fully exposed to the sufficient light intensity (light intensity higher than the light saturation point), but the lower leaves are short of light, resulting in the low utilization of light as a whole. In other words, the light receiving coefficient or the light receiving area changes for the worse.

On the other hand, varieties suitable for heavy manuring produce thick and small sized leaves extending vertically under heavy manuring. Assuming leaves to be evenly distributed in three dimensions within the space between the hills, light supply to each leaf is averaged, and hence the total supply of light to the plant as a whole is increased. Thus, the morphological characteristics of a variety are closely related to the degree of its response to heavy manuring through the light receiving coefficient (f).

Tsunoda placed great importance on this characteristic of the high response varieties with leaves standing erect, and he suggested that the greater proportion of the midrib, which functions as a pillar supporting the leaf blade, to the length of the leaf blade might be responsible for this leaf characteristic. Furthermore, Iwata & Baba (1961) found that silica application makes the leaves stand erect through the silicification of leaf epidermis, which brings about increased light-receiving efficiency. Varietal differences in silica absorption and silicification of epidermal cells could therefore exert a favorable influence by increasing the response to heavy manuring through the improvement of the light-receiving coefficient (f).

III. Varietal differences in lodging and response to heavy manuring

According to Seko (1957), there is a close relationship between lodging and the value of moment/breaking resistance; the greater the moment (culm length × top weight) and the less the breaking resistance of the lower internodes, the more easily does lodging occur. Lodging resistant varieties show in general either a short culm or a high breaking resistance. Varieties possessing very thick culm wall show greater resistance to breaking.

Sato (1957) reported that lodging takes place with increasing ease about three weeks after heading in accordance with the decrease of stored starch content in the base portion of the culm. It was suggested that the mechanical resistance of the parenchymatous cells of the culm might possibly be reduced by the disappearance of starch from the cells. Baba and Tajima (1960) recognized that among the varieties there exists a positive correlation between lodging resistance and starch content of culm + leaf sheath. This suggests that lodging resistance may to some extent be related to the response to heavy manuring through the starch content.

References

Baba, I. (1958). Nutritional studies on the occurrence of Helminthosporium leaf spot and "Akiochi" of the rice plant. *Bull. National Inst. Agr. Sci.* (Japan), Series D, No. 7: 1-157.

Baba, I. and Tajima, K. (1960). Yield and yield component of the rice plant as affected by the root-rot due to H_2S at the successive growing stage (in Japanese). Annual report of the 2nd Laboratory (1959), 1st Division of Plant Physiology, National Inst. Agr. Sci.: 54-57.

Baba, I. and Tajima, K. (1960). Studies on the varietal resistance to lodging in rice. (in Japanese) *ibid.* 36-45.

Baba, I. and Tajima, K. (1961). Root activity, photosynthesis, respiration, growth and yield of the rice as affected by root-rot due to H_2S. (in Japanese). Annual report of the 2nd Laboratory (1960), 1st Division of Plant Physiology, National Inst. Agr. Sci.: 20-24.

Iwata, I. and Baba, I. (1961). Studies on the varietal adaptability for heavy manuring in rice (2) Effect of silica on the adaptability of the rice plant for heavy manuring in relation to photosynthesis. *Proc. Crop. Sci. Soc.* Japan (in press).

Monji, M. and Saeki, I. (1953). Uber der Lichtfaktor in der Pflanzen gesellschaften und seine Bedeutung für die Stoffproduktion. *Jap. Jour. Bot.* 14: 22-25.

Murata, Y., Osada, A., Iyama, J. and Yamada, N. (1957). Photosynthesis of rice plants (IV) Plant factors constituting photosynthetic ability of the rice plants growing on paddy field. *Proc. Crop. Sci. Soc.* Japan 25 (3) 133-137.

Murata, Y., Osada, A. and Iyama, J. (1957). Studies on photosynthesis in rice plant (VII) Photosynthesis of rice plants grown under different condition in manuring. *ibid.* 26 (2) : 159-164.

Murata, Y. and Osada, A. (1961). Studies on the relationship between photosynthesis and varietal adaptability for heavy manuring in rice plant. I. The relationship between photosynthesis and adaptability for heavy manuring in medium-maturing rice varieties. *Proc. Crop. Sci. Soc.* Japan (in press).

Murata, Y. and Osada, A. (1961). Studies on the relationship between photosynthesis and varietal adaptability for heavy manuring in rice plant. II. The relationship between photosynthesis and adaptability for heavy manuring in early-maturing varieties. *ibid.* (in press).

Sato, S. (1957). Studies on the starch contained in the tissues of rice plant (IV) Starch content in the culm related to lodging. *Proc. Crop. Sci. Soc.* Japan 26 (1) : 19.

Seko, H. (1957), Samoto, K. and Suzuki, K. (1957). Lodging of rice plant in relation to several different cultural conditions (I) *Proc. Crop. Sci. Soc.* Japan 26 (2) : 90-92.

Takahashi, Y., Iwata, I. and Baba, I. (1959). Studies on the varietal adaptability for heavy manuring in rice. I. Varietal differences in nitrogen and carbohydrate metabolism affected by different supply of nitrogen *Proc. Crop. Sci. Soc.* Japan 28 (1) : 22-24.

Tsunoda, S. (1959). A developmental analysis of yielding ability in varieties of field crops. II. The assimilation-system of plants as affected by the form, direction and arrangement of single leaves. *Jap. Jour. Breeding* 9 (4) : 237-244.

Tsunoda, S. (1960 a). A developmental analysis of yielding ability in varieties of field crops. III. The depth of green colour and the nitrogen content of leaves *ibid.* 10 (2) : 107-111.

Tsunoda, S. (1960 b) High yielding ability of the rice variety in relation to the morphology and physiology of the plant in "Morphology and Physiology of the Rice Plant" (in Japanese) 180-228, Ed. T. Matsuo, Tokyo.

Yamada, N. and Ota, Y. (1958). Study on the respiration of crop plants (8) Effect of hydrogen-sulphide and lower fatty acids on the respiration of root in rice plant. *Proc. Crop. Sci. Soc.* Japan 27 (2) : 155-160.

VARIETY-NITROGEN INTERACTIONS IN RICE

M.F. Chandraratna[1]

In Ceylon, not only has the search for *indica* varieties manifesting high fertilizer response been particularly active, but numerous crosses have been effected between indigenous and introduced *indicas* with a view to the synthesis of high-response forms. The present paper reports recent tests conducted by Dr. L.H. Fernando, Botanist and Senior Agricultural Research Officer, and myself, of the more successful straight selections and hybrids. Moreover, an attempt has been made in it to clarify concepts relating to fertilizer response, and to develop methods of precise evaluation of differential response.

Three experiments were laid out in 1955-59 at the Central Rice Research Station, Batalagoda. For details of experimental methods, and of the soil of the experimental area, reference may be made to the previous paper by Chandraratna, Fernando and Weeraratna[2].

The experiments in the North East Monsoon 1955 tested two varieties at the following five nitrogen levels in a split-plot design of four replicates:

		lb. N/acre
n_0	—	0
n_1	—	20
n_2	—	40
n_3	—	60
n_4	—	80

The nitrogen fertilizer was distributed over main plots, and the varieties over sub-plots. In this and subsequent experiments, all plots received a basal dressing of 40 lb. P_2O_5/acre.

In the two experiments conducted during 1958-59, six varieties were tested in sets of three. Each set of three varieties was combined factorially with the following levels of nitrogen in four randomized blocks:

		lb. N/acre
n_0	—	0
n_1	—	30
n_2	—	60

The 1955 Experiment

Vellai Ilankalayan, one of the oldest and, at one time, one of the most extensively grown of Ceylon pure lines, was tested in the North East Monsoon 1955, at five levels of nitrogen, against *Murungakayan-3*, a selection made specifically for fertilizer response. The variance analysis of grain yields indicated the significance at the 0.1 per cent point, of the variety effect, the linear component of the nitrogen response, and of the linear nitrogen/varieties interaction.

TABLE 1

Grain Yields of Varieties at Various Nitrogen Levels in 1955 (lb/acre)

Varieties	Nitrogen in lb/acre					
	0	20	40	60	80	Mean ($\pm$ 30.5)
Vellai Ilankalayan	2252	2502	2622	2777	2764	2583
Murungakayan 3	3076	3568	3724	4133	4224	3745
	Standard Error: $\pm$ 68.3					
Mean ($\pm$ 79.0)	2664	3035	3173	3455	3494	3164

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The mean acre yields of grain given in Table 1 show that *Murungakayan-3* is superior to *Vellai Ilankalayan* at all nitrogen levels and that this superiority becomes increasingly pronounced with rising levels of nitrogen. The magnitude of the linear nitrogen/varieties interaction is an expression of the difference in the gradients of the response curves for the two varieties. A straight line and a parabola provided the best fit for the data relating to *Murungakayan-3* and *Vellai Ilankalayan* respectively; the equations are as follows:

Murungakayan-3 — $y = 3173 + 14.303\,x$

Vellai Ilankalayan — $y = 2253 + 13.51\,x - 0.0876\,x^2$

where $\underline{x}$ and $\underline{y}$ are the fertilizer level and the grain yield in lb/acre respectively.

The Experiment in 1958-59

Results of the two experiments are given in Table 2. In the 1958 experiment, all three varieties show nitrogen responses of similar magnitude, but *Bengawan* is significantly superior to *Ptb 16* in basic yield.

In the 1959 experiment, *H. 102* and *H. 105*, hybrids selected for nitrogen response, possess significantly higher linear components than *Murungakayan-302*. In H. 105, the positive quadratic component suggests that this hybrid should be able to exploit N levels higher than 60 lb/acre; the quadratic response though large is, however, not significant.

TABLE 2

Grain Yields of Varieties at Various Nitrogen Levels in 1958-59 (lb/acre)

Season	Varieties	Mean Yield without Nitrogen	Response to Nitrogen: Linear Component	Response to Nitrogen: Quadratic Component
North East Monsoon, 1958	Ptb 16	2215	1255	-55.0
	Siam 29	2468	1065	191.0
	Bengawan	2565	1099	129.5
		S.E.: ± 70.12	S.E.: ± 99.16	S.E.: ± 171.70
South West Monsoon, 1959	H. 102	2582	767.0	-245.0
	H. 105	3196	744.5	400.5
	Murungakayan 302	3029	309.0	-412.0
		S.E.: ± 92.31	S.E.: ± 130.54	S.E.: ± 227.11

Discussion

The Mitscherlich curve, $y = y_0 + d\,(1\text{-}10^{-kx})$, in which $\underline{y}$ and $\underline{x}$ symbolize yield and fertilizer dose respectively, and the parameter $\underline{k}$ defines curvature, has been extensively used in the evaluation of fertilizer response. This curve shows an asymptotic rise to a limiting value and does not provide for the yield decline which invariably accompanies excessive fertilisation. The second-degree polynomial of the form, $y = a + bx + cx^2$, where $\underline{y}$ is the yield at fertilizer level $\underline{x}$, possesses no such limitation, and is, moreover, a more versatile curve for the characterisation of varietal behaviour. The precise estimate of fertilizer response provided by this equation is the first differential coefficient: $dy/dx = b + 2\,cx$. The second differential coefficient estimates curvature, and is a measure of the rate at which fertilizer response falls off: $d^2y\,/\,dx^2 = 2\,c$.

When the range of fertilizer levels does not include extreme values, a straight line is often the curve of best fit, and may be regarded as a second-degree polynomial in which the coefficient $\underline{c} = o$. In the instance of both the straight line and the parabola, it is convenient to use the statistic $\underline{b}$ as the index of fertilizer response; $\underline{b}$ is the yield increase per unit fertilizer increment, of course, only with the rectilinear regression. The statistic $\underline{c}$, which has a maximum value of zero, indicates the capacity of the variety to respond to extreme levels of fertilizer.

In the instance of varieties possessing identical values of $\underline{b}$ and $\underline{c}$, the intercepts $\underline{a}$ of the curves on the $\underline{y}$ axis provide estimates of the basic yield. It is evident that the problem of breeding plants for fertilizer response ultimately resolves itself into selecting for maximum values of $\underline{a}$ and $\underline{b}$, and for a value of $\underline{c}$ approximating as closely as possible to zero. The manner in which these objectives may be achieved in rice selection is illustrated in the following comparison of the statistics appropriate to *Murungakayan-3*, a selection for nitrogen response, and *Vellai Ilankalayan* in the 1955 experiment; the nitrogen response of the latter is comparable to that of the unselected *Murungakayan* material:

	Values of Statistics		
	$\underline{a}$	$\underline{b}$	$\underline{c}$
Vellai Ilankalayan :	2253	13.51	-0.088
Murungakayan-3 :	3173	14.305	0

Limitation of experimental design does not permit the simultaneous testing of numerous varieties over a wide range of fertilizer levels. For most purposes, linear and quadratic components of response in trials at three nitrogen levels provide adequate estimates of relative sensitivity of varieties to nitrogen. The results of the 1959 trial illustrate the measure of success achieved in breeding for nitrogen response in the instance of *H. 102* and *H. 105*.

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